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OBTAINING GREAT ION CURRENTS

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[Note: The following is an article that appeared in the Izvestiya Akademii Nauk SSSR, Seriya Fizicheskaya, Volume IV, No. 2 (1940), which issue is entirely devoted to the works discussed at the conference on nuclear physics held at Kharkhov during 15-20 November 1939.

The English-language summary will be given first of this article.]

English-language Summary: In the present paper the method for obtaining strong ionic currents in a comparatively high vacuum (about 10^{-4} mm Hg) is described. The method is based on the high ionizing capacity of slow electrons. The path and number of electrons should be increased to enlarge the resulting ionic current. Two methods of applying electrical fields that lead to an increase of the effective electron path (oscillation) are discussed here. Analysis of experimental data obtained gives:

	I_+ / I_-	Pressure in MM/Hg
1) No oscillations	0.052	$1.36 \cdot 10^{-4}$ mm/Hg
2) Cylindrical field	0.108	$1.36 \cdot 10^{-4}$ mm/Hg
3) Nearly spherical field	0.680	$2. \cdot 10^{-4}$ mm/Hg

In our experiments with pressures given, ionic currents of several tens of milliamperes could be obtained. This method of obtaining great ionic currents has various advantages, as compared with existing methods. It requires no pressure difference between the space where the ionization takes place and the accelerating part of the apparatus; the construction of the apparatus is simple and it does not consume much energy - for example, in order to obtain ionic current of 65 milliamperes at the pressure of $4.36 \cdot 10^{-4}$ mm/Hg the required power is only 18 watts.

In a recent paper by G. W. Scott (Physical Review, 55, 994, 1939), the idea of obtaining ions by means of bombardment by slow electrons at the pressure of $3 \cdot 10^{-4}$ mm/Hg is made use. However his result of $I^{+}/I^{-} = 0.006$ ions per electron is erroneous, since it contradicts the well established facts concerning the ionizing capacity of electrons.

The methods ordinarily employed to obtain ions (channel rays, low-voltage arcs, capillary arcs, gas-magnetrons, etc) are characterized by two peculiarities. The first of these is that the ions are created in the form of a sharply concentrated beam or ray; and the second is that in order to form such a beam it is necessary to divide the entire apparatus into two parts with a large drop in pressure (note: an exception is the work of A. A. Slutskin, S. Ya. Braude and I. M. Vigdorchik; see their article in Zhurnal Eksperimental'noy i Teoreticheskoy Fiziki 5, 66, 1935, where they describe obtaining an ion current of 162 microamperes in a high vacuum of 10^{-5} mm/Hg.).

In a number of cases it is not necessary to concentrate the ions; sometimes it is even not desirable. At the same time, the presence in the apparatus of a separating vacuum greatly complicates things and creates a number of inconveniences during operations.

In this connection we posed the problem for ourselves of working out a method of obtaining a powerful beam of ions in a comparatively high vacuum, which method would not require the division of the apparatus into two parts. In this case we considered it possible to stop concentrating the ion beam in that part of the apparatus where the beam is created, by permitting its subsequent focussing.

The Essence of the Method: At the basis of the method worked out was the well known fact that the ionizing capacity of electrons depends upon their energy and in a definite region they possess their optimum value. Using for ionization such electrons one can depend upon obtaining great ion currents.

A simple calculation shows that for optimum conditions in one cm of path and for a pressure of 10^{-4} mm/Hg, under which condition many installations operate for the purpose of accelerating ions, the probability of ion formation is sufficiently significant, being equal approximately to 0.0025. Consequently, a large number of electrons possessing optimum energy traverse a considerable path.

The Experimental Installation: In our experiments we employed two different arrangements of the electrodes. In each of these the electrical field directing the electron beam serves simultaneously also as a field drawing out the ions. The disposition of the electrodes and the distribution of the potentials between them were so selected that the electron is forced to pass several times through the space where the formation of ions is occurring, thus making greater the effective path length. The distinguishing feature of the apparatus represented in figures 1 and 2 is in the nature of the electrical field arising between the corresponding electrodes.

Between the cathode K and the grid G_1 (figure 1) is created a field that accelerates the electrons. Part of the electrons passes through the grid G_1 and falls into the space between the grid G_1 and the grid G_2. The potential of grid G_2 is taken the same as the potential of the cathode or even still more negative; that is, the grid G_2 is an electrical mirror for the electrons. The electrons stopped between the grids G_1 and G_2 return back to the grid G_1, partially pass through the grid, are stopped near the cathode, and the entire process is repeated again. The ions forming in the space G_1-G_2 are drawn to the grid G_2 and partially pass through this grid. The grid G_2 is electrically connected to the cylinder L_1, which together with the cylinder L_2 (during imposition of the potential difference) forms the electrical lens; P is the Faraday trap which serves to measure the number of ions that have passed the electrical lens. The ions forming in the space between the cathode and the grid G_1 are drawn by the field in the direction toward the metallic plate S, whose potential is taken as somewhat more or negative than the potential of the cathode. The plate S has the shape of a portion of a sphere.

Figure 2 shows the configuration of the electrodes between which the ionization takes place - this is the shape used in the second series of tests.

The plate S in these experiments was connected with the cylindrical grid σ; and the grid G_1, with aid of which the electrons were accelerated, was replaced by the small ball B, held fast by the metallic rod C. For such a disposition in the region close to small ball a field is created in the well known form of a central field. This circumstance should favor the lengthening of the path traveled by an electron until its capture by the small ball B.

Results of Measurements: With the above-described apparatus we carried out measurements on the ratio I^+/I^- (namely, the ratio of the ionic current to the emission current) for various conditions; namely, for various gas pressures within the apparatus (in all the experiments, ordinary air served as the gas filling the apparatus), for various emission filaments, for various accelerating and stopping potentials.

Measurements of the vacuum were conducted by means of the Macleod manometer. For control of the vacuum measurements we employed our apparatus as an ionization manometer while conducting suitable hookups; in addition we carried out an experiment in the absence of a discharge when a high voltage was applied between the cylinders L_1 and L_2 (voltages up to 50 kv).

These control experiments indicate the efficiency of the readings from the Macleod manometer under our experimental conditions.

Comparison of the experimental data obtained gives the following table:

Experimental Values of I^+/I^- for Various Conditions

Conditions	I^- ma	I^+ ma	I^+/I^-	P mm/Hg
Absence of Oscillations	40	2.	0.052	$1.36 \cdot 10^{-4}$
Cylindrical Field	40	4.3	0.108	$1.36 \cdot 10^{-4}$
Field Close to Spherical	40	27.2	0.680	$2 \cdot 10^{-4}$

In our experiments we were able with the indicated pressures to obtain ionic currents ~~whose strengths were~~ of several tens of milliamperes. The described method for obtaining ~~great~~ high ionic currents possesses a number of advantages in comparison with present methods. This method does not require a drop in pressures between the space of ionization and the accelerating part of the apparatus; it is simple in construction and requires small power consumption (for example, in order to obtain a 65-ma ion current at a pressure of $4.36 \cdot 10^{-4}$ mm/Hg one needs a power expenditure of only 18 w).

From among the possible applications of this method one may note at this time the following two: 1) use of the ion source as a high-vacuum diffusion pump of high efficiency; and 2) application of great ion currents obtained by this method for the production of isotopes.

In the recently published work of Scott (Physical Review 55, 994, 1939) he employed the principle of obtaining ions by means of the collision of slow electrons for a pressure of $3 \cdot 10^{-4}$ mm/Hg. However, the result obtained by Scott (namely, $I^+/I^- = 0.006$ ion/electron) is erroneous, since it condradicts the well established data concerning the ionizing capacity of electrons.

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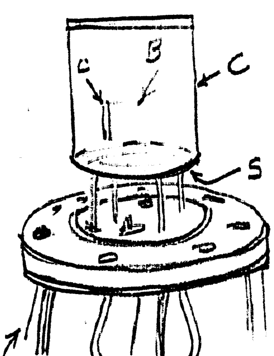

Figure 1. Schematic Drawing of the Ion Source

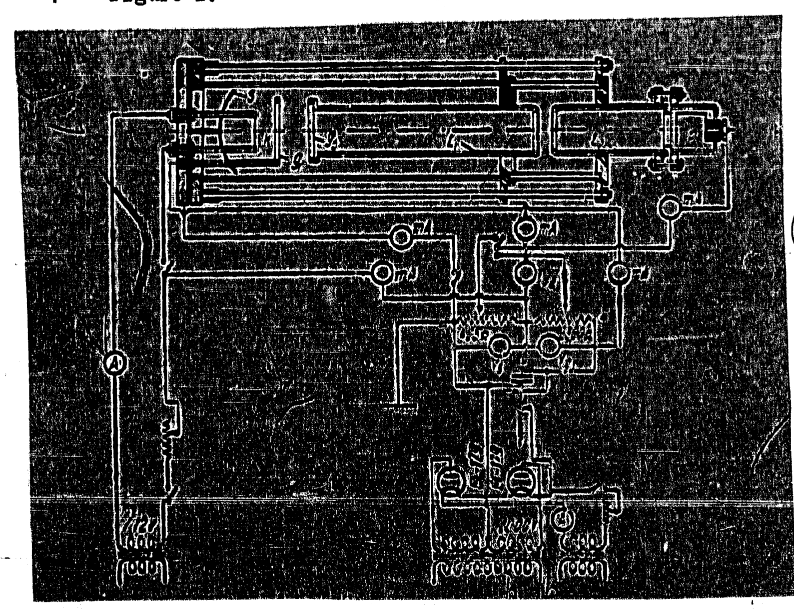

Figure 2. Configuration of the electrodes in the case of a field close to a field of central symmetry.